Adaptive Aerodynamics: Design and Evaluation of a Shape-Memory Alloy Actuated Variable-Camber Wing

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Aircraft wings are typically optimized for limited operating conditions and rely on hinged control surfaces to modify aerodynamic performance. This engineering research investigated whether a smooth, solid-state morphing wing using shape-memory alloy (SMA) actuation could increase aerodynamic lift through controlled camber change. The hypothesis was that increasing SMA actuation would increase trailing-edge deflection and produce a measurable lift increase at constant airflow and angle of attack. A 200 mm chord variable-camber wing was designed with a rigid leading section and a flexible trailing edge actuated by internal Nitinol SMA wires. Actuation level was controlled using pulse-width modulation (PWM), serving as the independent variable. Aerodynamic performance was first evaluated using low-Reynolds-number simulations. Simulated data were generated for trailing-edge deflection, lift force, electrical power consumption, and lift-to-power efficiency across PWM levels from 0% to 100%. The wing was then fabricated and tested in a custom-built wind tunnel at constant airflow and fixed angle of attack. Lift was measured using dual load cells, deflection using a linear potentiometer, and SMA temperature using a thermistor. Both simulated and experimental results showed increasing deflection with increasing actuation. Experimental lift increased by more than 100% relative to baseline and correlated strongly with camber change. Lift-to-power efficiency decreased at higher actuation levels, consistent with predicted thermal losses. Results support the alternate hypothesis and demonstrate the feasibility of SMA-actuated morphing wings for adaptive aerodynamic applications.

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